ELSEVIER
SciVerse ScienceDirect
Physics Procedia 24 (2012) 1178 – 1185
Physics Procedia

2012 International Conference on Applied Physics and Industrial Engineering

Fuzzy Controllers Based Multipath Routing Algorithm in MANET

Shangchao Pi[1], Baolin Sun[2]

[1]*College of Science Zhongyuan University of Technology*
Zhengzhou 450007, China
[2]*School of Computing Hubei University of Economics*
Wuhan 430205, China

Abstract

Mobile ad hoc networks (MANETs) consist of a collection of wireless mobile nodes which dynamically exchange data among themselves without the reliance on a fixed base station or a wired backbone network. Due to the limited transmission range of wireless network nodes, multiple hops are usually needed for a node to exchange information with any other node in the network. Multipath routing allows the establishment of multiple paths between a single source and single destination node. The multipath routing in mobile ad hoc networks is difficult because the network topology may change constantly, and the available alternative path is inherently unreliable. This paper introduces a fuzzy controllers based multipath routing algorithm in MANET (FMRM). The key idea of FMRM algorithm is to construct the fuzzy controllers with the help to reduce reconstructions in the ad hoc network. The simulation results show that the proposed approach is effective and efficient in applications to the MANETs. It is an available approach to multipath routing decision.

Keywords: MANET, fuzzy controllers, multipath routing, algorithm

1. Introduction

Conventional wireless mobile communications are normally supported by a fixed wired/wireless infrastructure. A mobile device would use a single-hop wireless radio communication to access a fixed base station that connect it to the wired/wireless infrastructure. In contrast, mobile ad hoc networks (MANETs) do not use any fixed infrastructure. The nodes in MANETs intercommunicate via single-hop and multi-hop paths in a peer-to-peer fashion. Intermediate nodes between a pair of communicating nodes act as a routers [1-5]. Thus, the nodes operate both as hosts and routers. The nodes in the ad hoc network could be potentially mobile, and so the creation of routing paths is affected by the addition and deletion of

 doi:10.1016/j.phpro.2012.02.176

nodes. The topology of the network may change randomly, rapidly, and unexpectedly [1-5]. A fundamental problem in ad hoc networking is how to deliver data packets among mobile nodes efficiently without predetermined topology or centralized control, which is the main objective of ad hoc routing protocols. Since mobile ad hoc networks change their topology frequently, routing in such networks is a challenging task.

Due to node mobility, node failures, and the dynamic characteristics of the radio channel, links in a route may become temporarily unavailable, making the route invalid. The overhead of finding alternative routes may be high and extra delay in packet delivery may be introduced. Multipath routing addresses this problem by providing more than one route to a destination node. Source and intermediate nodes can use these routes as primary and backup routes. Recent studies extensively focused on the multipath discovery of the on-demand routing protocols in order to alleviate single-path problems [5], such as high route discovery latency, frequent route discovery attempts and possible improvement of data transfer throughput. However, the studies on multipath utilization of the on-demand routing protocols to alleviate the same problems are not much available. The most characteristic operation in these areas is multipath, where messages are sent from one node to multiple recipients. Thus multipath routing is a challenging research problem [6-9]. There are several requirements posed on the multipath algorithm by the mobile ad hoc network environment. The existing multipath algorithms do not satisfy all of the requirements [6-9].

In [10, 11], they proposed the use of fuzzy logic controllers for the dynamic reconfiguration of edge and core routers. This reconfiguration allows for adjusting the network provisioning according to the incoming traffic and the QoS level achieved. The fuzzy logic is used due to the uncertainty associated with traffic estimation and to the non-linearity and lack of mathematical models able to estimate this traffic. A fuzzy controller is specified by fuzzy sets definition (membership function) and a set of rules (rule base). The priority index for each packet is determined based on number of hops the packet has suffered and the buffer size [11].

In this paper, we designed a fuzzy controllers based multipath routing algorithm in MANET (FMRM). The goal of the FMRM algorithm is to construct the fuzzy controllers with the help to reduce reconstructions in the ad hoc network.

The rest of the paper is organized as follows: In section 2, we introduce related works of the ad hoc network. Section 3 describes the fuzzy controller. Some simulation results are provided in section 4. Finally, the paper concludes in section 5.

2. Multipath Routing in MANETs

Multipath routing is very useful technique to find out the multiple paths between source and destination by using a single route discovery. Multipath routing protocols can attempt to find node-disjoint, link-disjoint, or non-disjoint routes. Node-disjoint routes have no nodes or links in common. Link-disjoint routes have no links in common, but may have nodes in common. Non-disjoint routes can have nodes and links in common. The multipath routing is more effective than the single path routing because multipath can provide load balancing, fault-tolerance, and higher aggregated bandwidth.

Multipath routing consists of finding multiple routes between a source and destination node. These multiple paths between source and destination node pairs can be used to compensate for the dynamic and unpredictable nature of ad hoc networks. Most routing protocols maintain routing tables to store the next hop towards the desired destination. Many routing protocols preserve a caching mechanism by which multiple routing paths to the same destination are stored. Multipath routing is essential for load balancing and offering quality of service. Fig. 1 shows multipath routing mobile ad hoc network.

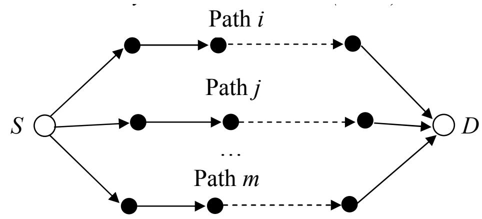

Figure 1. Multipath routing mobile ad hoc network

The Ad Hoc On-Demand Distance Vector (AODV) routing [5] is a reactive protocol, even though it still uses characteristics of a proactive protocol.

AOMDV[6] extends the prominent AODV to discover multiple loop-free and link-disjoint paths between the source and the destination in every route discovery. It uses the routing information already available in the AODV protocol as much as possible. To keep track of multiple routes, the routing entries for each destination contain a list of the next-hops along with the corresponding hop counts. All the next hops have the same sequence number. For each destination, a node maintains the advertised hop count, which is defined as the maximum hop count for all the paths. The protocol computes multiple loop-free and link-disjoint paths. Loop-freedom is guaranteed by using a notion of “advertised-hopcount”. Link disjointness of multiple paths is achieved by using a particular property of flooding. AOMDV can be used to find node-disjoint or link-disjoint routes. To find node-disjoint routes, each node does not immediately reject duplicate RREQs. Each RREQ arriving via a different neighbor of the source defines a node-disjoint path. Also, each node maintains a first hop list for each RREQ to keep track of the list of neighbors of the source through which a copy of the RREQ has been received.

AODVM [9] is an extension to AODV for finding multiple nodedisjoint paths. Intermediate nodes are not allowed to send a route reply directly to the source. Also, duplicate RREQ packets are not discarded by intermediate nodes. Instead, all received RREQ packets are recorded in an RREQ table at the intermediate nodes. The destination sends an RREP for all the received RREQ packets. An intermediate node forwards a received RREP packet to the neighbor in the RREQ table that is along the shortest path to the source. To ensure that nodes do not participate in more than one route, whenever a node overhears one of its neighbors broadcasting an RREP packet, it deletes that neighbor from its RREQ table. Because a node cannot participate in more than one route, the discovered routes must be node-disjoint.

3. Fuzzy Controller

3.1 Fuzzy Controller

The fuzzy logic was introduced by L. Zadeh [12] as a generalization of the boolean logic. The difference between these logics is that fuzzy set theory provides a form to represent uncertainties, that is, it accepts conditions partially true or partially false. Fuzzy logic is the best logic to treat random uncertainty, i.e., when the prediction of a sequence of events is not possible.

There are generally two kinds of fuzzy logic controllers [13, 14]. One is feedback controller, which is not suitable for the high performance communication networks. Another one, which is used in this paper, is shown in Fig. 2. The output of the fuzzy logic controller in Fig. 2 is used to tune the controlled system’s parameters based on the state of the system. This control mechanism is different from the conventional feedback control and considered as an adaptive control.

The specific features of the fuzzy controller depend on the model under control and performance measurement. However, in principle, in the fuzzy controller we explore the implicit and explicit relationships within the system and subsequently develop the optimal fuzzy control rules as well as a knowledge base.

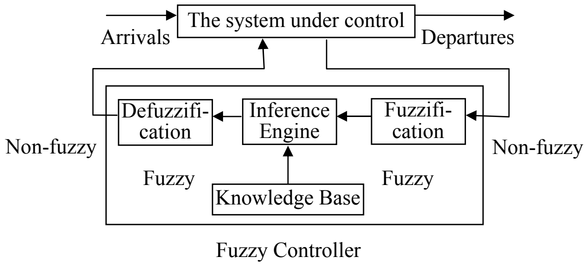

Figure 2. The fuzzy controller

3.2 Scheduler Controller

The fuzzy scheduler proposed here calculates the priority index of each packet. Here we consider all the inputs which decide the priority associated with the packet, unlike the previous scheduling schemes. The fuzzy scheduler uses three input variables and one output variable. The three input variables to be fuzzified are, the expiry time, and data rate of the packet and Queue length of the nodes to which the packet is associated with. The inputs are fuzzified, implicated, aggregated and defuzzified to get the crisp value of the output i.e., the priority index.

The linguistic variables associated with the input variables are low (L), medium (M), high (H), and very high (VH). For the output variable, priority index, 4 linguistic variables are used. They are, low (L), medium (M), high (H), and very high (VH). The membership functions of these variables are shown in the Fig. 3.

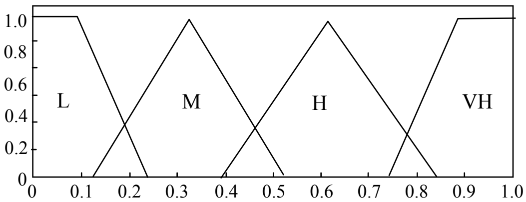

Figure 3. Scheduler membership functions

4. Simulation Experiments

4.1 Simulation Model

To conduct the simulation studies, we have used randomly generated networks on which the algorithms were executed [15]. This ensures that the simulation results are independent of the characteristics of any particular network topology. The results of the simulation are positive with respect to performance. We evaluated the FMRM algorithm using ns-2 simulator [16]. To effectively evaluate FMRM's performance, we compare it with other famous multicast routing protocols AOMDV [6], AODVM [9] for cost to control information, average link-connect time, the success rate to find the path and the feature of data transmission

A simulated field is 1000m × 1000m in which N=100 nodes are moving around. Simulations are run for 600 seconds. Each node moves randomly with a speed of 10 meter/sec. Table 1 lists the simulation parameters which are used as default values unless otherwise specified.

Table I. Simulation parameters

Number of nodes	100
Terrain range	1000m ×1000m
Transmission range	250m
Simulation time	600 seconds
Node's mobility speed	0-10m/s
Mobility model	Random way point
Channel bandwidth	1-3 Mbps
Links delay	20-200ms
Traffic type	CBR
Data payload	512 bytes/packet
Node pause time	0-10 seconds
Examined routing protocol	AOMDV, AODVM

During the experiment, we research FMRM mainly from packet delivery ratio, routing overhead ratio, and average end-to-end delay of data packets. The packet delivery ratio, routing overhead ratio, and average end-to-end delay of data packets are decided by the following formula:

1. Packet delivery ratio — the packet delivery ratio is a ratio of the correctly delivered data packets, and is obtained as follow.

$$\text{Packet delivery ratio} = \frac{\text{No. of packets delivered}}{\text{No. of packets sent}}$$

2. Routing overhead ratio — the routing overhead ratio is a ratio of the network control packets overhead and correctly delivered data packets, and is obtained as below.

$$\text{Routing overhead ratio} = \frac{\text{No. of control packets sent}}{\text{No. of packets delivered}}$$

3. Average end-to-end delay of data packets — it represents the average value of the time that the received data packets take to reach the destination from their origin. This parameter includes the time the nodes stay in the internal queues, the retransmissions at the MAC level, and the forwarding through multiple intermediate nodes.

4.2 Simulation Results

The packet delivery ratio displays the transmission efficiency of the network with the proposed algorithm. Fig. 4 show packet delivery ratio of routing methods according to the increase of node's maximum speed. As the nodes maximum speed increase, a packet delivery fraction of methods decreases. This because, in higher speeds, more frequent link breakage may occur and therefore a packet loss fraction is increased. This figure shows that our proposed algorithm performs best among tested methods. Our scheme can provide more chance an alternative path successfully. Thus, our FMRM algorithm is more reliable than AOMDV, AODVM.

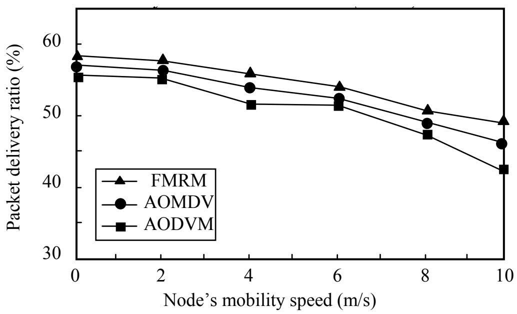

Figure 4. Comparison of packet delivery ratio.

The control packets are route discovery packets (RREQ, RREP) and route maintenance packets (RERR, HELLO). The routing overhead ratio displays the level of transmission overhead expenses of the network with the given protocol. Fig. 5 shows a comparison of routing overhead ratio. From the Fig. 5 we can see that when the node’s movement speed increases, FMRM’s routing overhead ratio is lower than that of AOMDV, AODVM.

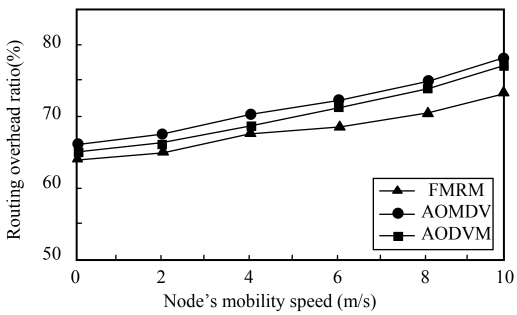

Figure 5. Comparison of routing overhead ratio.

Fig. 6 shows simulation result on the aspect of average end-to-end delay performance of routing methods by varying the node’s maximum movement speed from 0 to 10 m/s to increase mobility. The increase of movement speed induces more frequent topology change and therefore the probability of broken links grows. Broken links may cause additional route recovery process and route discovery process. Because of this reason, the average end-to-end delay of packet increases as node speed increases. From the Fig. 6 we can see that when the node’s mobility speed increases, proposed algorithm data transmission rate is lower than that of other methods. This is because the multipath extensions have stability routes and need smaller route discovery overheads. On the other hand, our scheme can provide more alternate paths in advance when the primary path is broken, resulting in less average end-to-end delay in higher mobility environment.

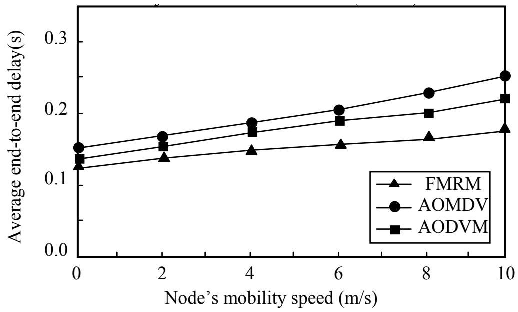

Figure 6. Comparison of end-to-end delay.

5. Conclusion

Due to the mobility of the nodes in ad hoc networks, the network topology changes frequently. Therefore, an efficient routing algorithm plays an important role for having better performance in ad hoc networks. This paper discusses the multipath routing problem in MANET. It presents a fuzzy controllers based multipath routing algorithm in MANET (FMRM). The key idea of FMRM algorithm is to construct the fuzzy controllers with the help to reduce the number of route reconstruction in the ad hoc network. The goal of the FMRM algorithm is to construct the fuzzy controllers with the help to reduce the number of route reconstruction in the ad hoc network. The multiple routes were efficiently selected, which result in higher packet delivery ratio, lower routing packets and lower end-to-end delay. Simulations were carried out with NS-2 and the effectiveness of the proposed method is validated in high load condition. It is an available approach to multipath routing decision.

Acknowledgment

This work is supported by The Young and Middle-aged Elitists' Scientific and Technological Innovation Team Project of the Institutions of Higher Education in Hubei Province (No. T200902), Key Scientific Research Project of Hubei Education Department (No. Q20091903, B20091904, D20102205).

References

[1]Baolin Sun, Layuan Li, "A QoS Multicast Routing Optimization Algorithms Based on Genetic Algorithm", Journal of Communications and Networks, 2006, Vol. 8, No. 1, pp. 116–122.

[2]Baolin Sun, Shangchao Pi, Chao Gui, et al., "Multiple Constraints QoS Multicast Routing Optimization Algorithm in MANET based on GA", Progress in Natural Science, 2008, Vol. 18, No. 3, pp. 331–336.

[3]Baolin Sun, Chao Gui, Hua Chen, and Yue Zeng, "An Entropy-Based Stability QoS Routing with Priority Scheduler in MANET using Fuzzy Controllers", Lecture Notes in Artificial Intelligence, Vol. 4223, Springer-Verlag Berlin Heidelberg, 2006, pp. 735–738.

[4]Baolin Sun, Chao Gui, Qifei Zhang, et al., "A multipath on-demand routing with path selection entropy for ad hoc networks", Journal of Software, 2008, Vol. 19, No. Suppl., pp. 112-120.

[5]C. E. Perkins, E. M. Royer, "Ad hoc On-Demand Distance Vector Routing (AODV) ", IETF RFC 3561, 2003.

[6]M. K. Marina and S. R. Das, "On-Demand MultiPath Distance Vector Routing in Ad hoc Networks", In Proceedings of the Ninth International Conference on Network Protocols (ICNP), California, IEEE Computer Society Press, 11-14 Nov, 2001, pp. 14-23.

[7]G. Parissidis, V. Lenders, M. May, B. Plattner, “Multi-path Routing Protocols in Wireless Mobile Ad Hoc Networks: A Quantitative Comparison”, Lecture Notes in Computer Science, 2006, Vol. 4003, pp. 313-326.

[8]X. Li, L. Cuthbert, “Node-Disjointness based Multipath Routing for Mobile Ad hoc Networks”, In Proceedings of the ACM International Workshop on Performance Evaluation of Wireless Ad-hoc, Sensor and Ubiquitous Networks, ACM Press, 2004, pp. 23-29.

[9]S. Motegi, K. Yoshihara, H. Horiuchi, “Proposal on Multipath Routing for Ad hoc Networks”, IEIC Technical Report, 2002, 102(441): 51-56, IN2002-125, Nov. 2002 (in Japanese).

[10]R. Zhang, and Y. Phillis, “Fuzzy Control of Queueing System with Heterogeneius Servers”, IEEE Trans. Fuzzy Systems, 1999, Vol. 7, No. 1, pp. 17–26.

[11]A. Thomas, C. Chellappan, and C. Jayakumar, “ANTHOC - QoS: Quality of Service Routing in Mobile Ad Hoc Networks using Swarm Intelligence”, The Second Asia Pacific Conference on Mobile Technology, Applications and Systems, Guangzhou, China, 15-17 November, 2005, 8 Pages.

[12]L. A. Zadeh, “Fuzzy sets”, Information and Control, 1965, Vol. 8, pp. 338–353.

[13]G. Alandjani, and E. Johnson, “Fuzzy Routing in ad hoc networks”, In Proceedings of the IEEE International Conference on Performance, Computing and Communications, Phoenix, Arizona, April, 2003, pp. 525–530.

[14]C. Gomathy, and S. Shanmugavel, “An Efficient Fuzzy Based Priority Scheduler for Mobile Ad hoc Networks and Performance Analysis for Various Mobility Models”, 2004 IEEE Wireless Communications and Networking Conference (WCNC 2004), Atlanta, USA, March, 2004, pp. 1087–1092.

[15]B. Waxman, “Routing of Multipoint Connections”, IEEE Journal on Selected Areas in Communications, 1988, Vol. 6, No. 9, pp. 1617–1622

[16]The Network Simulator – NS–2: http://www.isi.edu/ nsnam/ns/.